Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 3 (2015) 1046 – 1051

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

ATC perspectives of UAS integration in controlled airspace

J. Kamienski*, J. Semanek

The MITRE Corporation, McLean, VA 22102, USA

Abstract

There is a need to better understand the impacts unmanned aircraft systems (UAS) have on air traffic control (ATC) when they are integrated into the National Airspace System (NAS) in controlled airspace. An increasing number of UAS are requesting access to controlled airspace. Today, the larger UAS that are accessing busier controlled airspace consist mostly of Global Hawk and Predator-class aircraft. While these models of large UAS will continue to fly in the NAS, a small number of additional high-altitude long-endurance (HALE) UAS will be added to the traffic mix. Although the larger UAS flying in controlled airspace tend to fly in less congested areas, there is still an impact on ATC. Over the past several years, MITRE has been using a combination of techniques to determine the key impacts on controllers and the air traffic system. The analyses have shown that there are several areas where air traffic control is most affected by UAS flights. One of these areas is the filing of flight plans; especially for long-duration missions. Another difference is the flight profile of UAS. UAS flight profiles are frequently very different from traditional point-to-point routes that most manned aircraft fly. The impact on controllers is exacerbated by the fact that most of these UAS operating in controlled airspace use latitude/longitude waypoints to define their route instead of the more common named fixes or waypoints. The communications and control link for beyond visual line of sight operations can present additional challenges for controllers if there are delays in responses to clearances and maneuvering of aircraft. While these examples have some potential to exist for manned aircraft, they are more prevalent in UAS. One additional issue, unique to UAS, is the complete loss of the communications and control link. Throughout this research, MITRE has looked at potential ways of mitigating issues that arise from the different UAS challenges, and reviewed some of the pros and cons of these different approaches, including changes in procedures, automation, and policy.

Peer-review under responsibility of AHFE Conference

Keywords: RPA; UAS; ATC; Unmanned; Controllers

* Corresponding author. Tel.: +1-703-983-5028; fax: +1-703-983-1226.
E-mail address: jkamienski@mitre.org

Peer-review under responsibility of AHFE Conference
doi:10.1016/j.promfg.2015.07.169

1. Background

UAS access to the NAS has been increasing and is predicted to continue an upward trend[1]. The Federal Aviation Administration (FAA) is facing increased pressure to allow UAS to operate routinely in the NAS. The majority of these UAS platforms are small (less than 55 pounds), operating in Class G airspace, for a wide variety of mission uses: transmission line inspection, precision agriculture, real estate applications, law enforcement, etc. Large UAS flying at high altitudes, a subset of all UAS, today consist of mainly the Global Hawk operated by the Department of Defense (DOD) and the Predator-B operated by DOD and the Department of Homeland Security (DHS). In the foreseeable future, these operations are expected to continue, along with the addition of some commercial high altitude long endurance (HALE) aircraft. Global Hawks are mainly used in the U.S. for testing and training to prepare aircraft and pilots for overseas missions. Predator-B's are also used for training by DOD, as well as by DHS for monitoring the U.S. border. Commercial HALE aircraft have potential for applications that require station-keeping at high altitudes. Typical applications might include communications relay systems to augment satellites, providing internet access to a broad region, or observation similar to that done by satellites today.

The key difference between UAS and manned aircraft is the remote location of the pilot. Instead of being onboard, the pilot is located in a control station that may not even be in the same geographical part of the world as the aircraft itself. This means that all control instructions from the pilot to the aircraft must be sent over a data link that may be line-of-sight or relayed through satellites. The voice communications with ATC are also sent over this link and relayed from the aircraft, so that it can be picked up by the appropriate repeaters in the region.

The NAS is divided into several classes of airspace predicated on how busy the airspace is and where the airspace is located. Most current large UAS operations take place in Class A airspace. In the United States (U.S.), Class A airspace extends from 18,000 feet mean sea level (MSL) to Flight Level (FL) 600. In the NAS, all aircraft are required to see-and-avoid other aircraft. Mitigations for UAS lack of see and avoid such as chase aircraft, use of temporary flight restrictions, ground-based visual observers, and ground based sense and avoid (GBSAA) are required for safe flight when operating outside Class A. However, within Class A airspace, air traffic controllers provide positive separation for all aircraft. This means that UAS lack of ability to detect and avoid other aircraft is not a major issue in Class A airspace. Congestion varies widely across the NAS, from very busy around the northeast, to sparse along the northern and southern borders of the U.S. UAS operations generally take place in the uncongested regions, which minimizes their impact on air traffic control (ATC).

The NAS is made up of a combination of people, equipment, automation, policies, and procedures that keep air traffic safe and efficient. The FAA's transformative Next Generation Air Traffic System or NextGen, has a list of operational improvements (OIs) that describe the expected NAS enhancements. Most of the OIs involve busier airspace where UAS operations are not anticipated to take place in the near future. NextGen, and especially UAS integration into NextGen, must deal with the political, social, and ethical implications of change while keeping the system at least as safe as the existing system [2]. Although NextGen improvements are mostly focused on the busiest airspace, there are some aspects of it that will affect UAS operations, and UAS operations that will affect NextGen concepts.

The purpose of this research has been to better understand how large UAS fit into the NAS, especially their impact on ATC. The research has looked at both today's NAS as well as the predicted system in the next ten years. This research is one piece of numerous ongoing efforts at MITRE that focus on technologies, integration, procedures, and other UAS issues across the FAA and DOD.

2. Methodology

MITRE conducted a wide variety of activities to complete this research, including discussions with facilities and subject matter experts (SMEs), analyses of current operations, reviews of future operations, and human-in-the-loop experiments (HITLs).

Facility visits included ZOA (Oakland Center), ZMA (Miami Center), ZMP (Minneapolis Center), ZLA (Los Angeles Center), and ZAB (Albuquerque Center). Activities at the facilities included data analysis, interviews with controllers, management, and other facility representatives, as well as observations of the sectors where UAS operations generally take place. MITRE held discussions to address the problems and issues the facilities were experiencing with current UAS operations, as well as areas where UAS integration activities were successful. MITRE also held interviews with various UAS public agency operators to gain an understanding of operator/ATC interactions and their effect on UAS integration. In addition to the facilities, MITRE held discussions with various SMEs from industry, the FAA headquarters, the FAA Technical Center, and MITRE staff. These discussions highlighted critical areas where UAS operations present challenges.

MITRE conducted analyses of current operations including reviews of voice data, radar data, and incident records. A combination of sources were used, including the FAA's FALCON system which allows playback of recorded data, recordings of aircraft track data, review of records contained in the FAA's Certificate of Authorization (COA) On-line and spreadsheets with information about known UAS accidents and lost links. This information was put together to get a better picture of where and how operations take place today.

MITRE's review of future operations consisted of two main components. A variety of UAS forecasts were analyzed to get a better picture of the types and number of operations that are likely to be seen in the coming years. In addition, reviews of NextGen OIs and current FAA programs helped give a better understanding of what the future NAS would look like from a technology and procedures standpoint.

MITRE conducted HITLs in the MITRE lab to look at a variety of possible UAS situations [3,4]. The lab contains air traffic control simulators that create a mock-up of potential situations using a combination of recorded and injected traffic. The experiments explored issues related to multiple UAS in a sector, delays due to the control link, and UAS lost link events.

The results of these activities were combined to get a better picture of UAS operations both today and in the future.

3. Results

The research identified UAS impacts on air traffic controllers in five major areas: UAS flight planning and automation, the UAS control link, UAS-specific information and procedures, ATC training, and UAS interaction with the future NAS.

3.1. UAS flight plan filing and automation

The unique aspects of UAS flight plan filing creates issues for the air traffic controller that may result in increased workload. Current and forecast UAS operations reveal that missions can last for multiple days, perhaps even weeks or months. Between automation and the ease of changing out crew in a control station, UAS operations are less restricted by human endurance than manned aircraft. Current ATC automation is not designed to manage flights of this duration. Controller intervention may be required to extend a flight plan or close and reopen a new flight plan. This causes additional workload in the sector.

Typically, aircraft fly using standard fixes and published routes. Because of the UAS flight management automation systems, flight plans are often submitted as latitude/longitude points rather than traditional airways, fixes and routes. Although NAS automation systems will accept this format, controllers are not as familiar with latitude/longitude format with regard to route format. Latitude/longitude is not part of the standard map training, and is not used on a routine basis, so controllers must rely more heavily on aircraft route displays and other automation functions to visualize where the aircraft is going within their sector.

Most manned aircraft fly with the main intent of reaching their destination as quickly and efficiently as possible. UAS, on the other hand, often have mission profiles that are different from manned aircraft. This means that UAS may not be flying standard routes, may be performing unusual patterns and loiters within a sector or across sector boundaries, and the UAS pilot's objective is to execute a mission profile without shortcuts or diversions. These unusual operations make separation management a bigger challenge for controllers than standard manned aircraft.

3.2. UAS control link

Due to the relaying of the instructions that control the aircraft during beyond visual line of sight operations via the link and the use of the link for communication with controllers through satellites, there is the potential for issues with the command and control (C2) link. From a controller's perspective, the two biggest concerns are delays in the C2 link or latency, and a complete loss of link.

Delays in the communications and maneuvering of aircraft are not seen regularly in manned aircraft. C2 delays or latency can break a controller's workflow when UAS readback responses are slower than typical manned aircraft responses. This is a more significant problem in busy sectors, where UAS occasionally operate today. If the operations in busy sectors increase, this will become a greater concern. The delay in response can also lead to blocked transmissions; if a new manned aircraft tunes into the frequency and does not hear anyone talking, begins checking in, but then steps on a communication that was initiated by a pilot a couple seconds prior. Frequency management is often one of a controller's biggest tasks under normal circumstances, and UAS could increase that workload. Delays in aircraft maneuvering as a result of the C2 link latencies can also make it more difficult to judge maneuvers for separation.

If the communication and control link fails entirely, the pilot can no longer control the aircraft or talk to controllers. The aircraft will begin flying a pre-programmed procedure that will take it to a safe landing place or a termination point clear of population. In these cases, no clearances can be sent to the UAS, and instead all other aircraft must be maneuvered out of its way. In addition, the information about the preprogrammed procedure is not always readily available to the controller at the sector, creating a challenge for managing the rest of the traffic around it.

3.3. UAS-specific information and procedures

Because UAS operate in ways that are different from manned aircraft, controllers need access to information that is specific to UAS types and missions while working the sector, which will help promote UAS mission success, NAS safety, and ATC workload. This information can be provided through automation, briefings, training, reference manuals, or other methods. Items such as operator telephone numbers, lost link information, and mission-specific maneuvers are examples of specific information that controllers need at the sector. This information must be easily accessible to controllers and must be concise, so as to not burden controllers with searching through extraneous information while at the sector. Additionally, in the future procedures might have to be developed or modified for UAS operations that are different from how things are done with UAS today. For example, controllers need standardized procedures for handling lost link events in the NAS. Another area that needs to be proceduralized is the prioritization of UAS missions in the NAS versus other NAS activity. In some cases UAS conduct missions that could have law enforcement importance or national security implications. These prioritization policies need to be incorporated into air traffic directives. Wake turbulence categorization and associated separation minima may need to be revised for UAS integration.

3.4. ATC training

Current UAS training for facility operational personnel consists an eLearning and Management System (eLMS) training course available nationally to all controllers. It provides general UAS information and handling characteristics. In ATC facilities that routinely handle UAS locally development training has been created. Much of UAS training course development is localized to facilities. The training of controllers needs to be updated to include more details about UAS handling differences as compared to manned aircraft. Training on issues such as lost link, lost communications, wake turbulence and UAS platform-specific issues needs to be updated in national and local training modules. The fact that current large UAS have no NAS navigation database, UAS cannot accept visual ATC clearances, and current UAS have no airborne detect-and-avoid systems is information that is useful to a controllers for sector decision making and operational handling.

3.5. UAS interaction with the future NAS

While UAS operations are expected to change in the future, the NAS itself will also not stay the same. If a UAS is capable of meeting the airspace equipage requirements, it could fly in those areas that have such requirements and interact with the improvements in the same way as manned aircraft. Two major changes are to communications and wake turbulence.

Interactions between controllers and UAS pilots may change with NAS voice and data communication upgrades. The biggest potential for change to ATC is in the voice infrastructure, which may to be enhanced to accommodate a pilot located in a control station rather than the aircraft, to allow more efficient routing of communications such that it does not need to be relayed through the aircraft, where it has the potential for delays and for a complete loss of the line. Development of this infrastructure needs to consider how to make the communication routing transparent to the controller, so that frequency management does not become an even bigger challenge. The increase in data communications could help promote UAS activities. The long and complex routings many UAS fly are difficult to describe via voice. Datalink communications that interfaces with automation both on the UAS side and the ATC side could help reduce controller workload related to modifying UAS clearances.

Another consideration is that many UAS are lighter than a similarly-sized manned aircraft, due to the lack of similar avionics onboard, systems for supporting human life, and designs that allow for long-duration flights. Different wake categories may need to be established to support safe operations of these UAS. While wake is generally only a consideration in terminal airspace, and not today in Class A airspace, which could change with some UAS designs. This would require new training and procedures for en route controllers to manage wake characteristics.

4. Discussion

A significant distinction when contrasting manned aircraft from UAS from an ATC perspective is the fact that there is no pilot on board the UAS. Although Class A procedures mitigate the lack of ability to see-and-avoid, large UAS in that airspace still require different handling as compared to manned operations. Flight planning and automation, C2 latency and associated handling differences from manned aircraft could possibly become more significant issues for ATC than today's operations with the forecast growth of UAS in the NAS. Specifically, latency could affect ATC separation standards, thus decreasing NAS efficiency. Although this research focused on Class A, we postulate that latency effects are magnified in the terminal environment where ATC separation minima is decreased as compared to en route minima and so aircraft are in closer proximity to one another. Other Class A issues may include the controllers need for new information about UAS operations that is not available to them today, and that procedures may need to be changed to accommodate UAS. Identifying these issues has been the first major step, but work is still needed to determine the best ways to resolve them.

Acknowledgements

The authors would like to thank MITRE staff who led various components of this research, including Bill Foster, Mary Minnix, Matt DeGarmo, Maria Geffard, Wes Link, Thor Abrahamsen, Dan Kirk, and Joe Boyd. All of these people contributed to a greater understanding of UAS operations' impact on air traffic controllers.

Disclaimer

Neither the FAA nor the DOT makes any warranty or guarantee, expressed or implied, concerning the content or accuracy of these views.

Approved for Public Release; Distribution Unlimited. Case Number 15-0888

References

[1] The Teal Group. World Unmanned Aerial Vehicle Systems, Market Profile and Forecast 2014. 11th Edition, 2014.

[2] R. Van Dyk, D. Pariseau, R. Dodson, B. Martin, A. Radcliffe, E. Austin, Y. Haimes, E. Andrijcic, Z. Guo, J. Werner. Systems Integration of Unmanned Aircraft into the National Airspace: Part of the Federal Aviation Next Generation Air Transportation System. Systems and Information Design Symposium (SIEDS) IEEE, 2012.

[3] J. Helleberg, D. Maroney. UAS Operations in the National Airspace System: Human-in-the-Loop Simulation and Experimentation. Association for Unmanned Vehicle Systems International North America, Denver, CO. 2010.

[4] J. Kamienski, E. Simons, S. Bell, S. Estes. Study of Unmanned Aircraft Systems Procedures: Impact on Air Traffic Control. 29th Digital Avionics Systems Conference. Salt Lake City, UT. 2010.